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An evaluation of the relative abundance of the flat-tailed horned lizard (*Phrynosoma mcallii*) in 10 areas in southeastern California

1980

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ABSTRACT

The abundance of the flat-tailed horned lizard (*Phrynosoma mcallii*) was evaluated in ten 4.0-ha plots in southeastern California. Creosotebush (*Larrea tridentata*) and bursage (*Ambrosia dumosa*) were the predominant perennial plants in all plots. Densities of perennial plants and the abundance of harvester ants (*Veromessor pergandei* and *Pogonomyrmex* spp.) were also measured in plots. Indexes of *P. mcallii* in plots (*LI*) were computed as the sum of 15 times the number of lizards observed per man-hour and 5 times the number of horned lizard scats counted per man-hour. Mean numbers of foraging workers in nests of harvester ants were estimated by capture-recapture analysis. Indexes of harvester ant abundance in plots were computed from numbers of nests counted and mean numbers per nest.

Lizard abundance indexes were statistically uncorrelated with 6 of 8 variables based on attributes of perennial vegetation and numbers and sizes of harvester ant nests. Lizard abundance was highly correlated with aggregate perennial density ($r = 0.93$). Multiple regression analysis—with perennial density (P), perennial diversity (Δ_1) and harvester ant abundance (AI)—as independent variables yielded the following model for predicting the relative abundance of flat-tailed horned lizards:

$$LI = 75.0P + 8.6\Delta_1 - 0.04AI - 7.9$$

This equation explains about 91% of the observed variation in the dependent variable.

INTRODUCTION

The flat-tailed horned lizard (Phrynosoma mcallii) occurs in desert areas of southeastern California, southwestern Arizona, and adjoining portions of Sonora and Baja California Norte, Mexico. The species often exhibits apparently low desities in areas where it occurs. With regard to the relative abundance of lizards in San Diego County, Klauber (1939) commented: "Probably the rarest...[is]... Phrynosoma m'callii on the desert." Norris (1949) observed that near Palm Springs the capture of Phrynosoma mcallii "was not a common occurrence," and that, "If two specimens were taken in a day...collecting was good." However, between February 1961 and October 1964, 502 P. mcallii were collected (or found dead) along a 7-mile stretch of Highway 78 between the Coachella and East Highline Canals (Wilbur Mayhew, pers. comm.). In May 1963 Mayhew concluded that P. mcallii was the most abundant reptile occurring in the creosotebush scrub between these canals. In 1964, these horned lizards were not as abundant as in previous years, and by the early 1970's numbers of P. mcallii along this once well-populated roadway were further reduced.

Because of these observations and because of increasing use and development of desert areas in Riverside and Imperial Counties, concern as to the status of P. mcallii was expressed by Stewart (1971) and (in 1973) by staff of the Museum of Vertebrate Zoology in Berkeley. Similar views were expressed through the Planning Commission of Riverside County. The Office of Endangered Species of the U.S. Fish and Wildlife Service responded by designating P. mcallii a species whose status should be reviewed. Assessment of the distribution and abundance of this lizard, clarification of important characteristics of its habitats, and development of sound conservation policies are important needs, because this species often coexists with sources of natural gas, oil, geothermal energy and minerals, or occurrs in areas of value for agricultural or recreational uses.

In 1978 and 1979 the Bureau of Land Management (BLM) supported investigations of the status of P. mcallii in California (Turner, Medica and Hill, 1978; Turner et. al., 1980). The purpose of this work was to determine the local distribution and relative abundance of P. mcallii, to correlate these parameters with various habitat attributes, and to gather information on structure of populations and mobility of individuals.

Phrynosoma mcallii subsists almost entirely on ants. Pianka and Parker (1975) reported that 97% of all remains in stomachs of these lizards were ants, and examinations of scats led to similar conclusions (Turner et. al. 1978, 1980). Ants consumed were principally harvester ants: Pogonomyrmex californicus, P. magnacanthus and Veromessor pergandei. The 1978 work in California showed an inverse correlation between numbers of horned lizards and diversity of annual plants, but this relationship derived principally from the overwhelming preponderance of one annual plant (Plantago insularis) in the area where horned lizards were most abundant.

In 1980 we renewed our attempt to understand environmental factors influencing the abundance of this lizard. Five pairs of sections were selected for inspection. One section of each pair showed good habitat (based on assessments in 1979) and one section of each pair was apparently poor habitat. The general plan was to examine the relative abundance of P. mcallii in ten areas and to assess numbers of harvester ants and abundance and diversity of vegetation in these same areas.

PROCEDURES

General orientation was carried out between April 29 and May 1, 1980. At this time study sites 1-4 were inspected, with particular attention to Plot 1-the area designated as Plot 15 during the 1978 field work (Turner et. al. 1978). Scats of P. mcallii were collected in this area and retained for subsequent reference. On May 1, two P. mcallii were observed on Plot 3 near Wolf Well, on the Ocotillo Wells State Vehicular Recreational Area. Sanford Porter, a graduate student in the Department of Zoology and Entomology at Brigham Young University, spent April 29 and 30 demonstrating procedures used to estimate numbers of worker ants in colonies. Locations of the ten study areas are set forth in Table 1.

Each study area was a 200 by 200 m square staked in a 50 m grid so that the area could be systematically inspected. Field work began on May 5 in Plot 1 and continued until July 11, with from 3-5 days being devoted to each area.

Counts of lizards and scats

Each plot was inspected by two field workers for one and one-half hours each morning. The workers walked slowly through the area in a systematic manner, counting any P. mcallii observed and scats of horned lizards. All scats observed were collected. The first five were preserved and the others discarded outside the area so that no duplication in counting would occur. Counts of lizards and scats were converted to counts per man-hour and an index of horned lizard abundance (LI) calculated for each plot:

$$LI = 15(\text{lizards}\cdot\text{man-hour}^{-1}) + 5(\text{scats}\cdot\text{man-hour}^{-1}) \qquad (1)$$

Counts of plants

All perennials (including herbaceous species and grasses) occupying fifty 50 x 2 m belt transects in each plot were tallied by species. Annual plants were collected in twenty-five 0.25-m^2 quadrats in Plots 1 and 2, but this part of the work was abandoned because plants were so dry that identification was usually impossible.

Diversities of perennial plants were computed as Δ_1 (Hurlbert 1971). This measure is defined as the proportion of potential interspecific encounters between individuals, assuming every individual in the census can encounter all other individuals:

$$\Delta 1 = \left[\underline{N}/(\underline{N}-1)\right] \left(1 - \sum_{i=1}^{S} \underline{P}_i^{\,2}\right) \tag{2}$$

where $\underline{N}$ = total number of individuals in the census

$\underline{S}$ = number of species in the census

$\underline{P}_i = \underline{N}_i \,/\, \underline{N}$

$\underline{N}_i$ = The number of individuals of the $\underline{i}$th species in the collection.

Estimating the abundance of harvester ants

The first step in estimating the abundance of harvester ants was to enumerate all active nests of *Pogonomyrmex* spp. and *Veromessor pergandei* in study areas. The second step was to estimate mean numbers of foraging workers per nest.

The general procedure followed was the mark-recapture technique, with foraging harvester ants marked with fluorescent dyes dissolved in ether. The original intent was to mark solitary foraging ants of the genus

Pogonomyrmex as well as individuals from columns of foraging *Veromessor pergandei*. In practice, nests of *Veromessor* were generally more numerous than those of *Pogonomyrmex* and always more conspicuous. Hence, most of the work on ants centered on nests of *Veromessor pergandei*. We recognize that the total populations of nests include ants that do not forage, but the foragaing workers make up that portion of nests available to horned lizards.

Ants became active at dawn and continued to forage until surface temperatures became too high. This activity period was about 2-3 hours in duration. As air and ground temperatures increased ants became more active and, if collected in an agitated condition, rarely survived the marking procedure. All samples, therefore, were taken soon after dawn.

Preliminary tests with nests of *Veromessor pergandei* in late April showed that some nests contained more than 10,000 workers. Hence, initial samples of *Veromessor* workers were from around 300 to 600 individuals. With additional experience, we found that the size of the first sample could be varied according to the size of the foraging column. The procedures we used were essentially those described by Porter and Jorgensen (unpubl. ms.). Ants were collected using an aspirator. They were then etherized. Most ants reacted well to this treatment and apparently recovered completely. In several instances, however, ants died before they could be processed. Some of our experiences suggested that ants from particular nests were more vulnerable than others. In one case ants were collected from six nests and etherized. Ants from one of the nests died. Later ants were collected from a group of nests including the one from which the ants which died were taken. Again, ants from this same nest died after etherizing. After ants were etherized they were removed from their container and counted. Adhering sand grains were removed from ants by sifting through a piece of window screen, and gravel was removed using a friction table. Ants were then marked with Day-Glo^R fluorescent printing ink (5 g in 50 ml of ethyl ether). We used a Clairol Fresh Hold^R hair spray bottle producing a fine mist. After ants had revived they were returned to their nest. In high winds it was necessary to shield the nest before releasing ants so they would not blow away before disentangling themselves and reentering the nest. A day later ants were collected from the nest again. The second sample was usually about the same size as the first. These ants were etherized, counted and placed under an ultraviolet lamp. Marked ants fluoresced brightly, so that numbers of recaptures could be readily ascertained.

Numbers of workers $\underline{N}$ were estimated from numbers of ants marked in first sample ($\underline{a}$) and numbers of marked ants recaptured ($\underline{r}$) in a second sample ($\underline{n}$) as recommended by Bailey (1952):

$$\underline{N} = \underline{a}(\underline{n}+1)/(\underline{r}+1) \qquad (3)$$

Mean numbers of workers per nest were calculated from nest sampling data for each plot. Numbers of workers of _Pogonomyrmex_ spp. were estimated only for two nests in Plot 9 and one nest in Plot 10. The plot-specific estimates were used for Plots 9 and 10; for other plots where _Pogonomyrmex_ nests were counted we used the mean number of workers in the three nests as the the estimate of number of workers per nest.

An index of harvester ant abundance (AI) was computed for each plot by i) multiplying the number of active nests of Veromessor pergandei (VN) by the mean number of workers per nest (VD), ii) multiplying the number of active nests of Pogonomyrmex spp. (PN) by the mean number of workers per nest (PD), iii) summing these values and dividing by 10^4:

$$\underline{AI} = 10^{-4}(\underline{VN}\cdot\underline{VD} + \underline{PN}\cdot\underline{PD}) \qquad (4)$$

RESULTS

Plot-specific summaries of sampling data are given in Appendixes 1-10. Capture-recapture data for 60 nests of harvester ants analyzed in plots are summarized in Appendix 11. Table 2 summarizes selected variables for all 10 plots.

Only five P. mcallii were observed in the course of 106 man-hours of search, about half the rate (0.09 per man-hour) experienced during searches of 458 sections in 1979 (Turner et. al. 1980). 114 scats were counted (1.08 per man-hour), again distinctly lower than the rate in 1979 (4.8 per man-hour). In contrast to much of the earlier work, all horned lizards and most of the scats were observed in areas of desert pavement. The predominating shrubs in every plot were Larrea tridentata and Ambrosia dumosa although Dalea emoryi (Plot 1) and Coldenia palmeri (Plot 6) were unusually abundant in some plots. Numbers of perennial species counted in plots were usually from 5 to 7, so species richness was low. Aggregate numbers of perennials counted ranged from 134 (Plot 9) to 1398 (Plot 4), and diversities from 0.213 (Plot 3) to 0.769 (Plot 6).

For nine of the ten plots we can compare the relative abundance of P. mcallii inferred from 1979 data (Table 1) with the 1980 abundance indexes (Table 2). These findings were in good accord, although the contrasts between Plots 7 and 8 and 9 and 10 in 1980 were not as pronounced as the differences in the 1979 data. Recall, however, that the 1979 observations were distributed over entire 1 mi^2 sections, whereas the 1980 work was carried out in 4-ha areas within sections. A non-parametric rank correlation test of the indexes from the two years (Snedecor 1956: 190) gives $r_s = 0.8$, which is significant at the 1% level.

Table 3 gives the correlation matrix for the variables in Table 2. Abundance of P. mcallii, as expressed by the abundance index, was significantly correlated only with aggregate perennial density (Fig. 1) and density of Ambrosia. These two variables are significantly correlated with each other. It is also clear that because of the low numbers of Pogonomyrmex nests counted, and because of the way in which the ant abundance index was computed, total ant nests, total Veromessor pergandei nests and the harvester ant abundance index are all mutually correlated.

The abundance of P. mcallii was next examined in a stepwise multiple regression analysis using aggregate perennial denisty (P), perennial diversity (Δ_1), and the harvester ant abundance index (AI) as independent variables. Table 4 summarizes the results of this analysis. The model resulting explains about 91% of the observed variation in the dependent variable and predicts horned lizard abundance as:

$$\underline{LI} = 75.0\underline{P} + 8.6\Delta_1 - 0.04\underline{AI} - 7.9 \qquad (5)$$

Table 5 summarizes observed horned lizard abundance indexes and model predictions.

DISCUSSION

The foregoing analysis exhibits some similarities to and differences from assessments of data acquired in 1978 and 1979. Indexes of abundance of P. mcallii in 1978 (based solely on lizards observed per man-hour) were "uncorrelated with at least 6 of 9 independent variables based on attributes of annual and perennial vegetation and numbers of nests of ants consumed by horned lizards" (Turner et. al. 1978). Horned lizard abundances were significantly correlated with densities and diversities of annual plants, but not with similar measures of perennials. This is in sharp contrast with the 1980 work, which showed a remarkably high correlation between lizard abundance indexes and aggregate numbers of perennials counted.

In view of these new findings, it is worth looking at the 1978 perennial data again (Table 6). Standard linear regression analysis shows lizard abundance to be uncorrelated with perennial densities, but it is clear that the plots with low perennial densities were generally poorly populated with horned lizards. In fact, a rank correlation test gives $\underline{r}_s = 0.92$, and this value is significant at the 1% level. Based on the 1980 data and reexamination of the 1978 data, we believe that aggregate perennial density should be given attention in future attempts to discriminate between good and poor habitats for P. mcallii. Although it is true that the horned lizard may occupy some barren habitats "...where vegetation is sparse or lacking"(Stebbins 1966), we feel that when aggregate perennial densities are <250·ha^{-1}, the habitat is not likely to be favorable for P. mcallii. Almost all areas examined in 1978 and 1980 with high abundances of P. mcallii exhibited aggregate perennial densities of >1,000·ha^{-1}.

One of the continuing lines of thought in work on Phrynosoma mcallii has been that there should be a clear relationship between the abundance of the lizards and the ants upon which they feed. This idea has been reinforced by observations of Phrynosoma cornutum and harvester ants in New Mexico (Whitford and Bryant 1979). However, this has been an elusive quest in southeastern California. Observations in 1978 and 1979 gave only equivocal support to this presumed relationship. Although horned lizards observed per man-hour in 1978 were uncorrelated with active nests of harvester ants, the ant variable did enter the three-term regression model of lizard abundance (Turner et. al. 1978). In 1979, counts of horned lizards were significantly correlated with counts of nests of Veromessor pergandei, but not with counts of nests of Pogonomyrmex spp. (Turner et. al. 1980). Estimating numbers of worker ants in foraging columns was a distinct improvement over techniques used in 1978 and 1979 when only nests were counted. Work during the 1980 season showed that numbers of Veromessor peregandei workers in nests far exceeded those of Pogonomyrmex (Appendix 11). It also appears that there may be geographic variations in mean colony sizes of Veromessor. Although horned lizard abundance indexes in 1980 were uncorrelated with counts of nests of either species (Table 3), the relationship between lizard abundances and harvester ant abundance indexes warrants further examination (Fig. 2).

The lack of a significant statistical correlation between these variables stems from the very low lizard abundance index in Plot 5, where a high abundance index for harvester ants was obtained. If Plot 5 is withheld from the analysis, there is a significant positive correlation between lizard abundance and harvester ant abundance ($\underline{r}$ = 0.71, $\underline{F}$ = 7.2, $\underline{F}_{0.05}$ = 5.3). Because there is no apparent reason to eliminate Plot 5 from the analysis, we comment on this point only to emphasize that some random sampling error in Plot 5 may be obscuring a relationship.

The 1979 and 1980 work never implicated Pogonomyrmex spp. as a factor of importance in determining the abundance of Phrynosoma mcallii, although these ants may be consumed in substantial numbers in some areas (Table 10, Turner et. al. 1978). This situation is hard to evaluate because the nests of Pogonomyrmex are much less conspicuous than those of Veromessor and may be undercounted.

The 1980 work certainly showed that estimates of the abundance of harvester ants are significantly improved if colony sizes are taken into account. We now know that numbers of foraging workers (per nest) of Veromessor pergandei far exceed those of Pogonomyrmex spp. A clear-cut relationship between abundances of P. mcallii and the ants on which it feeds remains to be demonstrated. While the lizards clearly require this resources, lizard abundance is apparently influenced by other factors as well.

ACKNOWLEDGMENTS

We thank Sanford Porter for indispensable assistance and advice during the planning of the harvester ant capture-recapture program. Larry Foreman and Lillian Olech gave valuable aid in planning and administration of this project. We thank Maurice Getty and Mark Jorgensen, Anza-Borrego Desert State Park, for assistance in establishing a study area in the Ocotillo Wells State Vehicular Recreational Area.

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Table 1. Locations of ten plots used in studies of Phrynosoma mcallii in southeastern California in 1980. Habitat ratings are based on counts of scats and lizards in 1979 (Turner et. al. 1980, Appendix 1).

Plots	Range (E)	Township (S)	Section		Habitat rating
1	12	17	18	600 m south of Hwy. 98 at Imperial County 15 mile marker. About 25 miles west of El Centro (see Yuha Basin Topo.).	17
2	11	17	16	400 m north of Highway 98 at Imperial County 11 mile marker. About 25 miles west of El Centro (see Yuha Basin Topo.).	5
3	8	11	25	100 yards west on first wash north of Wolfe Well. In Recreational Vehicle Area near Ocotillo Wells (see Shell Reef Topo.).	85
4	9	12	14	9½ miles west of Hwy. 86 on Hwy. 78. 100 hundred yards north of Hwy. at this point (see Shell Reef Topo.).	*
5	11	15	32	2.2 miles north of Hwy. 80 (at Plaster City) along road paralleling Gypsum Company's railroad. About 14 miles west of El Centro (see Plaster City Topo.).	0
6	12	14	7	3.5 miles west of main conning tower in Superstition Mountain Naval Bombing Area. About 20 miles west of El Centro (see Superstition Mountain Topo.).	37

Plots	Range (E)	Township (S)	Section	Specific location	Habitat rating
7	20	16	15	1 mile northwest of S34, just north of juncture of S34 and Interstate 8. About 40 miles east of El Centro (see Ogilby Topo.).	25
8	20	16	2	2.5 miles north of Interstate 8 on S34. About 40 miles east of El Centro (see Ogilby Topo.).	0
9	10	12	15	3.5 miles west of the junction of Highways 78 and 86. Two hundred meters north of hummocks 40 miles west of El Centro (see Kane Spring NW Topo.).	0
10	10	12	18	7 miles west of the junction of Highways 78 and 86. 150 meters north on service road, which is just east of transformer installation, 40 miles west of El Centro (see Kane Spring NW Topo.).	23

* Not evaluated in 1979.

Table 2. Data pertaining to horned lizards, perennial plants and harvester ants in 10 plots in southeastern California in 1980.

Plots	Number of *Phrynosoma mcallii* counted	Number of horned lizard scats counted	Horned lizard abundance index	Aggregate density of perennial plants ($n \cdot ha^{-1}$)	Diversity of perennials	Number of active nests of *Veromessor pergandei*	Number of active nests of *Pogonomyrmex* spp.	Mean number of workers per nest (*Veromessor*)	Mean number of workers per nest (*Pogonomyrmex* spp.)	Ant abundance index
1	0	14	10.0	2326	0.705	27	0	16.5	-	44.6
2	0	12	5.0	810	0.706	25	2	7.9	-	19.9
3	1	29	13.3	2480	0.213	19	0	12.0	-	22.8
4	3	23	17.8	2796	0.659	65	3	12.2	-	79.5
5	0	1	0.4	1020	0.460	47	0	12.4	-	58.3
6	1	21	13.3	2064	0.620	9	2	5.7	-	5.2
7	0	6	2.5	724	0.446	0	4	-	-	0.2
8	0	2	0.8	1172	0.332	9	2	6.7	-	6.1
9	0	0	0	268	0.604	0	7	-	0.5	0.4
10	0	6	2.5	1094	0.326	11	1	16.5	0.7	18.2

Table 3. Correlation matrix for variables listed in Table 2. Numbers across top of table match numbers of variables in left-hand column.

	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Horned lizard abundance index	0.551	0.686	0.926	0.194	0.468	0.480	-0.265	0.466
(2) Abundance of *Larrea tridentata*	–	0.116	0.581	0.312	0.435	0.437	-0.154	0.535
(3) Abundance of *Ambrosia dumosa*	–	–	0.808	-0.483	0.252	0.305	-0.591	0.296
(4) Aggregate abundance of perennials	–	–	–	0.024	0.496	0.531	-0.498	0.559
(5) Diversity of perennials	–	–	–	–	0.398	0.360	0.235	0.336
(6) Total harvester ant nests	–	–	–	–	–	0.995	-0.278	0.966
(7) Total nests of *Veromessor pergandei*	–	–	–	–	–	–	-0.373	0.975
(8) Total nests of *Pogonomyrmex* spp.	–	–	–	–	–	–	–	-0.404
(9) Harvester ant abundance index	–	–	–	–	–	–	–	

Table 4. Summary table of multiple regression analysis involving horned lizard abundance indexes, aggregate perennial density, perennial diversity and harvester ant abundance indexes in 10 plots in southeastern California.

Variables entered	Multiple R	Multiple R^2	F-value to enter
Aggregate density of perennials	0.926	0.857	47.8
Diversity of perennials	0.946	0.894	2.5
Harvester ant abundance index	0.954	0.910	1.0

Table 5. Observed horned lizard abundance indexes and predictions by a 3-term regression model.

Plot	Observed horned lizard abundance indexes	Predicted abundance indexes
1	10.0	13.7
2	5.0	3.4
3	13.3	11.8
4	17.8	15.7
5	0.4	1.3
6	13.3	13.0
7	2.5	1.2
8	0.8	3.7
9	0	-0.5
10	2.5	2.4

Table 6. Aggregate densities of perennial plants and numbers of *Phrynosoma mcallii* observed per man-hour in eight plots in 1978. Ranks are given in parentheses.

Plots	Horned lizards per man-hour	Aggregate perennial density (n ha)
10	0 (6½)	1017 (3)
11	0 (6½)	180 (80
12	0 (6½)	183 (7)
13	0 (6½)	294 (5)
14	0.12 (4)	272 (6)
15	1.14 (1)	1203 (2)
16	0.14 (3)	2140 (1)
17	0.48 (2)	315 (4)

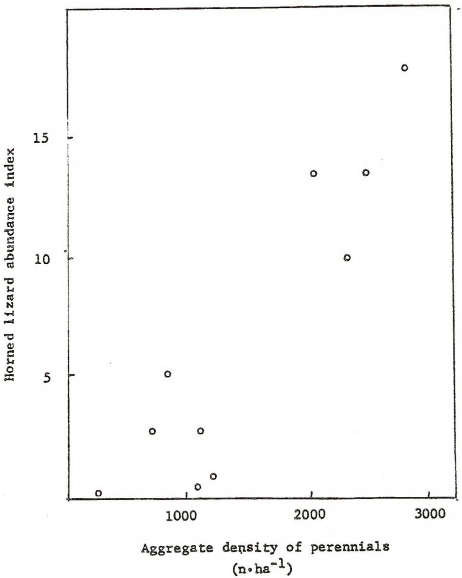

Fig. 1. Relative abundance of horned lizards (*Phrynosoma mcallii*) and aggregate density of perennial plants in 10 plots in southeastern California

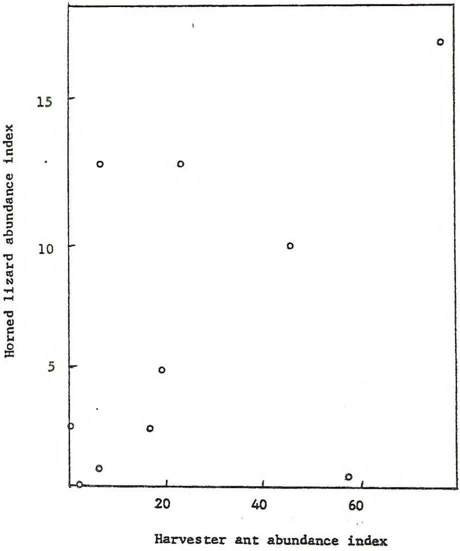

Fig. 2. Relative abundance of horned lizards (Phrynosoma mcallii) and harvester ant abundance in 10 plots in southeastern California

Appendix 1

Sampling data in Plot 1 during the spring of 1980

Dates of work	May 7-9
Number of man-hours spent in searches	7
Phrynosoma mcallii counted	0
Horned lizard scats counted	14
Lizards per man-hour	0
Scats per man-hour	2.0
Lizard abundance index	10.0
Counts of perennial plants in transects	
Ambrosia dumosa	385
Coldenia palmeri	69
Dalea emoryi	323
Hymenoclea salsola	7
Larrea tridentata	385
Total perennials counted	1163
Aggregate perennial density ($n \cdot m^{-2}$)	
Diversity of perennials (Δ_1)	0.705
Numbers of active ant nests	
Veromessor pergandei	27
Pogonomyrmex spp.	0
Number of nests used in estimating worker abundance	
Veromessor pergandei	5
Pogonomyrmex spp.	0
Range of estimates of worker abundance (thousands)	
Veromessor pergandei	5.7-35.1
Pogonomyrmex spp.	-
Mean number of workers per nest (thousands)	
Veromessor pergandei	16.5
Pogonomyrmex spp.	-
Ant abundance index	44.6

Appendix 2

Sampling data in Plot 2 during the spring of 1980

Dates of work	May 13-16
Number of man-hours spent in searches	12
Phrynosoma mcallii counted	0
Horned lizard scats counted	12
Lizards per man-hour	0
Scats per man-hour	1.0
Lizard abundance index	5.0
Counts of perennial plants in transects	
Ambrosia dumosa	175
Dalea emoryi	3
Eriogonum inflatum	24
Fouquieria splendens	7
Hilaria rigida	15
Krameria grayi	67
Larrea tridentata	112
Opuntia spp.	2
Total perennials counted	405
Aggregate perennial density ($n \cdot m^{-2}$)	
Diversity of perennials (Δ_1)	0.706
Numbers of active ant nests	
Veromessor pergandei	25
Pogonomyrmex spp.	2
Number of nests used in estimating worker abundance	
Veromessor pergandei	10
Pogonomyrmex spp.	0
Range of estimates of worker abundance (thousands)	
Veromessor pergandei	1.3-21.5
Pogonomyrmex spp.	-
Mean number of workers per nest (thousands)	
Veromessor pergandei	7.9
Pogonomyrmex spp.	-
Ant abundance index	19.9

Appendix 3

Sampling data in Plot 3 during the spring of 1980

Dates of work	May 20-23
Number of man-hours spent in searches	12
Phrynosoma mcallii counted	1
Horned lizard scats counted	29
Lizards per man-hour	0.08
Scats per man-hour	2.42
Lizard abundance index	13.4
Counts of perennial plants in transects	
Ambrosia dumosa	1092
Atriplex polycarpa	6
Dalea emoryi	3
Encelia virginensis	1
Hilaria rigida	4
Larrea tridentata	134
Total perennials counted	1240
Aggregate perennial density ($n \cdot m^{-2}$)	
Diversity of perennials (Δ_1)	0.213
Numbers of active ant nests	
Veromessor pergandei	19
Pogonomyrmex spp.	0
Number of nests used in estimating worker abundance	
Veromessor pergandei	4
Pogonomyrmex spp.	0
Range of estimates of worker abundance (thousands)	
Veromessor pergandei	5.8-20.7
Pogonomyrmex spp.	-
Mean number of workers per nest (thousands)	
Veromessor pergandei	12.0
Pogonomyrmex spp.	-
Ant abundance index	22.8

Appendix 4

Sampling data in Plot 4 during the spring of 1980

Dates of work	May 28-30
Number of man-hours spent in searches	9
Phrynosoma mcallii counted	3
Horned lizard scats counted	23
Lizards per man-hour	0.33
Scats per man-hour	2.56
Lizard abundance index	17.8
Counts of perennial plants in transects	
Ambrosia dumosa	638
Atriplex canescens	362
Dalea emoryi	28
Hilaria rigida	12
Larrea tridentata	358
Total perennials counted	1398
Aggregate perennial density ($n \cdot m^{-2}$)	
Diversity of perennials (Δ_1)	0.659
Numbers of active ant nests	
Veromessor pergandei	65
Pogonomyrmex spp.	3
Number of nests used in estimating worker abundance	
Veromessor pergandei	11
Pogonomyrmex spp.	0
Range of estimates of worker abundance (thousands)	
Veromessor pergandei	7.1-27.2
Pogonomyrmex spp.	-
Mean number of workers per nest (thousands)	
Veromessor pergandei	12.2
Pogonomyrmex spp.	-
Ant abundance index	79.5

Appendix 5

Sampling data in Plot 5 during the spring of 1980

Dates of work	June 3-6
Number of man-hours spent in searches	12
Phrynosoma mcallii counted	0
Horned lizard scats counted	1
Lizards per man-hour	0
Scats per man-hour	0.08
Lizard abundance index	0.4
Counts of perennial plants in transects	
Ambrosia dumosa	365
Coldenia palmeri	66
Dalea emoryi	3
Hilaria rigida	2
Larrea tridentata	52
Hymenoclea salsola	20
Opuntia spp.	2
Total perennials counted	510
Aggregate perennial density ($n \cdot m^{-2}$)	
Diversity of perennials (Δ_1)	0.460
Numbers of active ant nests	
Veromessor pergandei	47
Pogonomyrmex spp.	0
Number of nests used in estimating worker abundance	
Veromessor pergandei	10
Pogonomyrmex spp.	0
Range of estimates of worker abundance (thousands)	
Veromessor pergandei	3.3-21.5
Pogonomyrmex spp.	-
Mean number of workers per nest (thousands)	
Veromessor pergandei	12.4
Pogonomyrmex spp.	-
Ant abundance index	58.3

Appendix 6

Sampling data in Plot 6 during the spring of 1980

Dates of work	June 10-13
Number of man-hours spent in searches	9
Phrynosoma mcallii counted	1
Horned lizard scats counted	21
Lizards per man-hour	0.11
Scats per man-hour	2.33
Lizard abundance index	13.3
Counts of perennial plants in transects	
Ambrosia dumosa	593
Coldenia palmeri	155
Dalea emoryi	57
Eriogonum inflatum	8
Hilaria rigida	145
Krameria grayi	2
Larrea tridentata	72
Total perennials counted	1032
Aggregate perennial density ($n \cdot m^{-2}$)	
Diversity of perennials (Δ_1)	0.620
Numbers of active ant nests	
Veromessor pergandei	9
Pogonomyrmex spp.	2
Number of nests used in estimating worker abundance	
Veromessor pergandei	6
Pogonomyrmex spp.	0
Range of estimates of worker abundance (thousands)	
Veromessor pergandei	2.4-9.7
Pogonomyrmex spp.	-
Mean number of workers per nest (thousands)	
Veromessor pergandei	5.7
Pogonomyrmex spp.	-
Ant abundance index	5.2

Appendix 7

Sampling data in Plot 7 during the spring of 1980

Dates of work	June 17-20
Number of man-hours spent in searches	12
Phrynosoma mcallii counted	0
Horned lizard scats counted	6
Lizards per man-hour	0
Scats per man-hour	0.5
Lizard abundance index	2.5
Counts of perennial plants in transects	
Ambrosia dumosa	117
Larrea tridentata	243
Olneya tesota	2
Total perennials counted	362
Aggregate perennial density (n·m^{-2})	
Diversity of perennials (Δ_1)	0.446
Numbers of active ant nests	
Veromessor pergandei	0
Pogonomyrmex spp.	4
Number of nests used in estimating worker abundance	
Veromessor pergandei	0
Pogonomyrmex spp.	0
Range of estimates of worker abundance (thousands)	
Veromessor pergandei	-
Pogonomyrmex spp.	-
Mean number of workers per nest (thousands)	
Veromessor pergandei	-
Pogonomyrmex spp.	-
Ant abundance index	0.2

Appendix 8

Sampling data in Plot 8 during the spring of 1980

Dates of work	June 24-27
Number of man-hours spent in searches	12
Phrynosoma mcallii counted	0
Horned lizard scats counted	2
Lizards per man-hour	0
Scats per man-hour	0.17
Lizard abundance index	0.83
Counts of perennial plants in transects	
Ambrosia dumosa	471
Dalea spinosa	1
Fouquieria splendens	5
Larrea tridentata	92
Olneya tesota	3
Opuntia spp.	5
Stephanomeria pauciflora	9
Total perennials counted	586
Aggregate perennial density ($n \cdot m^{-2}$)	
Diversity of perennials (Δ_1)	0.332
Numbers of active ant nests	
Veromessor pergandei	9
Pogonomyrmex spp.	2
Number of nests used in estimating worker abundance	
Veromessor pergandei	6
Pogonomyrmex spp.	0
Range of estimates of worker abundance (thousands)	
Veromessor pergandei	2.7-13.2
Pogonomyrmex spp.	-
Mean number of workers per nest (thousands)	
Veromessor pergandei	6.7
Pogonomyrmex spp.	-
Ant abundance index	6.1

Appendix 9

Sampling data in Plot 9 during the spring of 1980

Dates of work	July 1-3
Number of man-hours spent in searches	9
Phrynosoma mcallii counted	0
Horned lizard scats counted	0
Lizards per man-hour	0
Scats per man-hour	0
Lizard abundance index	0
Counts of perennial plants in transects	
Ambrosia dumosa	20
Atriplex canescens	75
Eriogonum inflatum	1
Larrea tridentata	34
Olneya tesota	4
Total perennials counted	134
Aggregate perennial density ($n \cdot m^{-2}$)	
Diversity of perennials ($\Delta 1$)	0.604
Numbers of active ant nests	
Veromessor pergandei	0
Pogonomyrmex spp.	7
Number of nests used in estimating worker abundance	
Veromessor pergandei	0
Pogonomyrmex spp.	2
Range of estimates of worker abundance (thousands)	
Veromessor pergandei	-
Pogonomyrmex spp.	0.48-0.51
Mean number of workers per nest (thousands)	
Veromessor pergandei	-
Pogonomyrmex spp.	0.5
Ant abundance index	0.4

Appendix 10

Sampling data in Plot 10 during the spring of 1980

Dates of work	July 8-11
Number of man-hours spent in searches	12
Phrynosoma mcallii counted	0
Horned lizard scats counted	6
Lizards per man-hour	0
Scats per man-hour	0.5
Lizard abundance index	2.5
Counts of perennial plants in transects	
Ambrosia dumosa	436
Hilaria rigida	2
Larrea tridentata	109
Total perennials counted	547
Aggregate perennial density ($n \cdot m^{-2}$)	
Diversity of perennials (Δ_1)	0.326
Numbers of active ant nests	
Veromessor pergandei	11
Pogonomyrmex spp.	1
Number of nests used in estimating worker abundance	
Veromessor pergandei	5
Pogonomyrmex spp.	1
Range of estimates of worker abundance (thousands)	
Veromessor pergandei	7.1-38.3
Pogonomyrmex spp.	0.7
Mean number of workers per nest (thousands)	
Veromessor pergandei	16.5
Pogonomyrmex spp.	0.7
Ant abundance index	18.3

Appendix 11 (conl.)

Plots	Dates	Number of ants originally marked (a)	Number of ants in second sample (n)	Number of recaptures (r)	Estimated number of workers
6	June 5-6	401	413	16	9,765
		203	181	14	2,463
		397	377	22	6,524
		398	384	21	6,965
		387	379	32	4,456
		406	379	39	3,857
7		-	-	-	-
8	June 24-25	352	313	13	7,894
		347	343	8	13,263
		293	278	29	2,725
		205	241	11	4,134
		200	199	8	4,444
		210	221	5	7,770
9	July 1-2	60	39	4	480
		50	50	4	510
10	July 8-9	498	501	30	8,064
		487	472	5	38,391
		496	461	31	7,161
	July 9-10	50	58	3	737
		403.	399	13	11,514
		297	295	4	17,582

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Appendix 11

Capture-recapture data pertaining to harvester ant nests in southeastern California. All nests are of Veromessor pergandei except those in Plot 9 and the first nest listed in Plot 10.

Plots	Dates	Number of ants originally marked (a)	Number of ants in second sample (n)	Number of recaptures (r)	Estimated number of workers
1	May 7-9	817	611	42	11,628
		675	534	62	5,732
		523	529	18	14,588
		601	538	20	15,426
		491	499	6	35,071
2	May 13-16	423	520	45	4,791
		587	558	73	4,434
		203	194	13	2,828
		190	178	25	1,308
		505	454	48	4,689
		94	110	2	3,478
		502	508	14	17,034
		536	466	15	15,644
		534	483	11	21,538
		289	286	22	3,606
3	May 20-21	494	551	19	13,634
		526	489	32	7,810
		655	517	57	5,850
		278	223	2	20,757
4	May 28-29	500	484	33	7,132
		500	489	8	27,222
		510	434	13	15,846
		497	490	18	12,843
		503	502	31	7,907
		498	533	33	7,822
		501	511	27	9,161
		497	500	14	16,600
		500	508	24	10,180
		496	494	28	8,466
		493	489	21	10,980
5	June 3-4	400	394	14	10,533
		389	420	8	18,196
		409	192	4	15,787
		403	427	7	21,560
		302	323	14	6,523
	June 5-6	305	274	7	10,484
		387	374	9	14,512
		296	284	24	3,374
		403	387	11	13,030
		398	399	15	9,950